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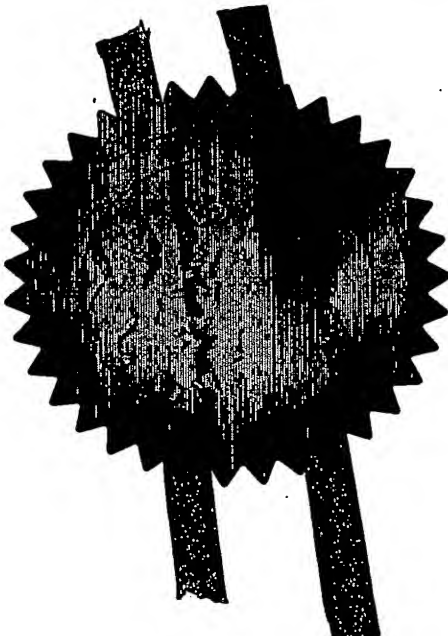
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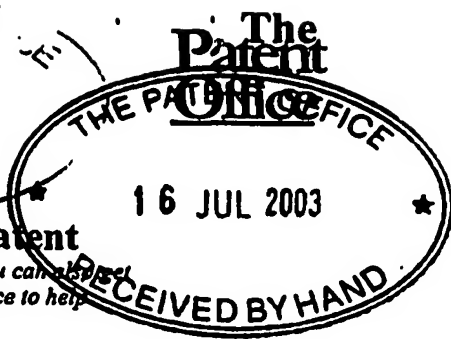
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Dated 21 September 2004

16 JUL 2003  
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The Patent Office

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16 JUL 2003

1.	Your reference	BP-09-0364		
2.	Patent application number (The Patent Office will fill in this)	0316658.4		
		17JUL03 E823129-1 D02826 P01/7700 0.00-0316658.4		
3.	Full name, address and postcode of the or of each applicant (underline all surnames)	Kanthal Limited Inveralmond Perth PH1 3ED		
Patents ADP number (if you know it)				
If the applicant is a corporate body, give the country/state of its incorporation		UNITED KINGDOM		
4.	Title of the invention	SILICON CARBIDE HEATING ELEMENTS		
5.	Name of your agent (if you have one)	Phillips & Leigh 5 Pemberton Row London EC4A 3BA United Kingdom		
"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)				
Patents ADP number (if you know it)		1289001		
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number	Country	Priority application number (if you know it)	Date of filing (day / month / year)
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application		Date of filing (day / month / year)
8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. See note (d))	Yes		

**Patents Form 1/77**

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**Continuation sheets of this form**

Description	5
Claim(s)	2
Abstract	1
Drawing(s)	4 + 4 <i>RM</i>

10. If you are also filing any of the following, state how many against each item.

**Priority documents**

**Translation of priority documents**

Statement of inventorship and right to grant of a patent (*Patents Form 7/77*)

Request for preliminary examination and search (*Patents Form 9/77*) 1

Request for substantive examination (*Patents Form 10/77*) 1

Any other documents  
(please specify)

11. I/We request the grant of a patent on the basis of this application.

Signature

Date

16<sup>th</sup> July 2003

12. Name and daytime telephone number of person to contact in the United Kingdom 020 7822 8888  
J.C. Boff

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DUPLICATE

## Silicon Carbide Heating Elements

- Silicon carbide heating elements conventionally are manufactured in the form of solid rods or cylindrical tubes, typically in diameters between 3mm and 110mm diameter.
- 5 Other cross sections are also possible, such as square or rectangular tubes, but are not in common use.

- Elements of a tubular cross-section are more economical to produce, using less silicon carbide than solid elements, and most silicon carbide elements used in industrial
- 10 furnaces feature a tubular construction.

- The power availability of any radiant heating elements is a function of its radiating surface area, and the capability of any given element type is usually expressed in watts per square cm of that radiating surface.

15

- In the case of tubular silicon carbide elements, only the external surface area is considered as useful radiating surface as there is no radiative heat transfer from the inner surfaces of the tube to the surroundings.
- 20 Silicon carbide is a relatively expensive ceramic material, particularly in the grades used in the manufacture of high temperature electric heating elements, so the use of less material would have a significant cost benefit

- The applicant has realised that if the ratio between the useful radiating surface and the cross-sectional area of the heating elements is increased, additional power may be
- 25 provided from an element of similar cross-sectional area to a conventional tubular or solid element, or alternatively a similar power from a smaller and lighter element, while using less mass of silicon carbide.

- 30 Accordingly the present invention provides strip form silicon carbide heating elements.

Preferably the heating elements are non-hollow.

Preferably the heating elements have a cross-sectional aspect ratio of greater than 3:1, more preferably greater than 5:1, yet more preferably greater than 10:1.

- 5 By aspect ratio is meant the ratio of the width to thickness of the strip.

Further features of the invention are made clear in the claims in the light of the following illustrative description, and with reference to the drawings in which:-

- 10 Fig. 1 shows a cross section of a conventional tubular heating element  
Fig. 2 shows the tubular element unrolled to form a strip element in accordance with the present invention;  
Fig. 3 shows a U-shaped 3 part heating element in accordance with the present invention;  
15 Fig. 4 shows a U-shaped one part heating element in accordance with the present invention;  
Fig. 5 shows a sinusoidal heating element in accordance with the present invention; and  
Fig. 6 shows a cross section of a curved strip element in accordance with the present  
20 invention.

In Fig. 1 a conventional tubular heating element 1 has a diameter  $D$  and wall thickness  $W$ . The surface area that can radiate is defined by the perimeter  $\pi D$  of the element. The cross sectional area of the material of the tube approximates to  $\pi DW$ .

25

In Fig 2, the tube is shown unrolled to form a strip 2 of length  $\pi D$  and thickness  $W$ . Again, the cross sectional area of the material of the tube approximates to  $\pi DW$ , but the surface area that can radiate is given by the perimeter  $2\pi(D+W)$  of the element. Unrolling the tube effectively doubles the radiating surface while leaving the material  
30 cross sectional area unchanged.

Additionally, the overall area of the tube 1 is  $\pi D^2/4$  whereas that of the strip 2 is  $\pi DW$ . So the ratio of area of strip to tube is  $4W/D$ . For a tube of diameter 40mm and wall thickness 5mm this results in a ratio of the overall area of the strip to tube of 0.5. By reducing the overall area of the element, a smaller hole in a furnace wall can be considered.

This heating section may be flat, but for many uses, it is anticipated that the heating section will be bent one or more times, to suit installation in various types of equipment, but especially in indirect electric resistance furnaces.

Figs 3. and 4 show one possible shape (a U) for the heating section. In Fig. 3 a 3-part heating element comprises a simple U-shaped strip 3 providing a high resistivity hot zone, connected to low resistance 'cold ends' 4,5 of conventional form, where the resistivity of the cold end is lower than that of the heating section and/or has a larger cross-sectional area. Terminal ends 6,7 serve for electrical connection to a power supply.

Fig. 4 shows a single piece heating element comprising a simple U-shaped strip having a U-shaped body 8 defining a high resistivity hot zone, and legs defining low resistance cold ends 9,10 and terminal ends 11,12. Modifying silicon carbide to provide regions of differing resistivity in this manner is known technology.

Other shapes of element are envisaged where one or more heating sections may be shaped with more than one bent section in order to conform with the shape of the equipment into which the element(s) will be fitted and/or provide convenient connection to either single phase or 3-phase electric power supply. For example, a W shaped element can readily be made. For a 3-phase heating element three strips may be joined to form a star or other configuration.

In Fig. 5, a generally U-shaped element 13 comprises a straight leg 14 and a sinusoidal leg 15 giving a greater radiating surface for the length of the element than would be provided by an element with two straight legs.

In Fig. 6, the strip 16 is curved in at least part of its length, rather than flat, so as to provide additional rigidity along its length. Where the strip is bent to form a U it is preferable that the strip is not curved where bent, but only on the straight.

- 5 Silicon carbide elements of substantially U-shape are known, and have previously been manufactured using a tubular or solid cylindrical heating section. The bend may be formed either by casting in a mould having the shape of the U, for example by slip-casting, but slip-casting is a non-preferred and relatively expensive method of manufacture for silicon carbide heating elements.
- 10 Casting techniques limit the particle size of silicon carbide material that conveniently can be used in manufacture, and where material with coarse grains is required, casting is not seen as a practical manufacturing method. Also, should it be desired to manufacture the heating elements in a high density, reaction-bonded grade of material, then again, slip-casting is a non-preferred route of manufacture, as the
- 15 casting material or slip must contain both silicon carbide and carbon, and it is not easy to cast such bodies in a controlled or repeatable fashion.

- Where volume production of silicon carbide elements is required, the method of manufacture preferred is by extrusion, where silicon carbide grains, or mixtures of
- 20 silicon carbide and carbon, are blended with binders and plasticisers, so they can be extruded through suitable dies, or die and pin sets, where hollow sections are to be produced. [There may be applications where it could be advantageous for the strip to be hollow (less material required, lighter in weight, easier to bond if 3-piece, lower potential for thermal shock) and the present invention contemplates hollow strips.]
- 25 Extrusion is a closely controlled and repeatable process, suitable for volume production of high quality electric heating elements in silicon carbide.

As the extruded material must be plastic, in order to extrude, then it is possible to change its shape by bending or forming after extrusion has taken place, but before drying and firing. Consideration has been given to bending or forming conventional rods or tubes from which silicon carbide elements normally may be produced, but  
5 there is a major disadvantage inherent in this procedure: Bending the shape extends the length of the exterior circumference of the bend, and reduces the length of the interior circumference. Consequently, material on the outside of the curve is stretched, reducing its density, and material on the inside of the face is compressed, increasing the density or crumpling the material.

10

With substantially laminar heating sections the thickness of the cross section can be made rather small, thus minimising the difference in circumference between the inner and outer lengths of the curve, and thus minimising changes in the material density, and any distortion or disruption of the extruded material.

15

For test purposes the applicant has made silicon carbide heating elements by extrusion having cross sections of 5mm thickness and 45mm width (aspect ratio 9:1) and 3 mm thickness and 36mm width (aspect ratio 12:1).

20 Once formed, the strip shaped elements can be subject to any of the normal processing steps for silicon carbide heating elements – e.g. impregnation, glazing, metallisation of terminals.

In the present invention a strip-form silicon carbide heating element is provided  
25 having a higher radiating surface area to volume ratio than a conventional tubular element.



## CLAIMS

1. A strip-form silicon carbide heating element.
- 5 2. A heating element as claimed in Claim 1, in which the element is non-hollow.
3. A heating element as claimed in Claim 1 or Claim 2, in which the cross sectional aspect ratio is greater than 3:1.
4. A heating element as claimed in Claim 3, in which the cross sectional aspect ratio is greater than 5:1.
- 10 5. A heating element as claimed in Claim 4, in which the cross sectional aspect ratio is greater than 10:1.
6. A heating element as claimed in any one of Claims 1 to 5, in which the element comprises non-strip form cold ends.
- 15 7. A heating element as claimed in any one of Claims 1 to 5, in which portions of the strip have a lowered resistivity and form cold ends.
8. A heating element as claimed in any one of Claims 1 to 7, in which the strip form element is generally U-shaped.
9. A heating element as claimed in any one of Claims 1 to 8, in which the strip is curved in cross-section in at least part of its length.
- 20 10. A heating element as claimed in any one of Claims 1 to 9, in which the heating section comprises a recrystallised self-bonded silicon carbide material
11. A heating element as claimed in any one of Claims 1 to 9, in which the heating element comprises reaction bonded or reaction sintered silicon carbide.
- 25 12. A method of making a heating element as claimed in any one of Claims 1 to 11, in which a strip preform is made by extrusion, and is bent to shape after extrusion.

13. A method as claimed in Claim 12, in which cold ends are made separately to the heating section, and later joined to it.
14. A method as claimed in Claim 12, in which cold ends are formed integrally with the element.
- 5 15. A method as claimed in any one of Claims 12 to 14, in which the heating section is recrystallised, to form a self-bonded silicon carbide material.
16. A method as claimed in any one of Claims 12 to 14, in which the material of the extruded preform is such that the final product will comprise reaction bonded or reaction sintered silicon carbide.

ABSTRACT

5 A strip-form silicon carbide heating element is provided having a higher radiating surface area to volume ratio than a conventional tubular element.

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Fig. 2

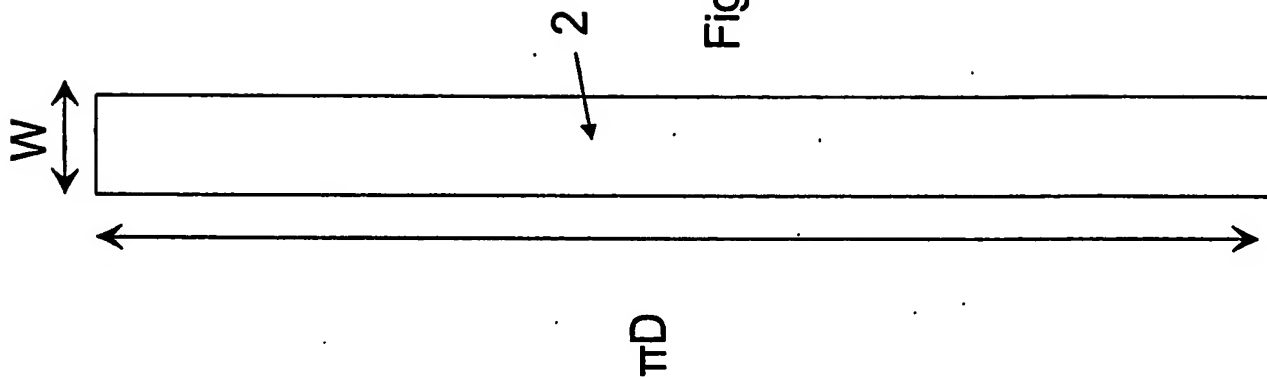
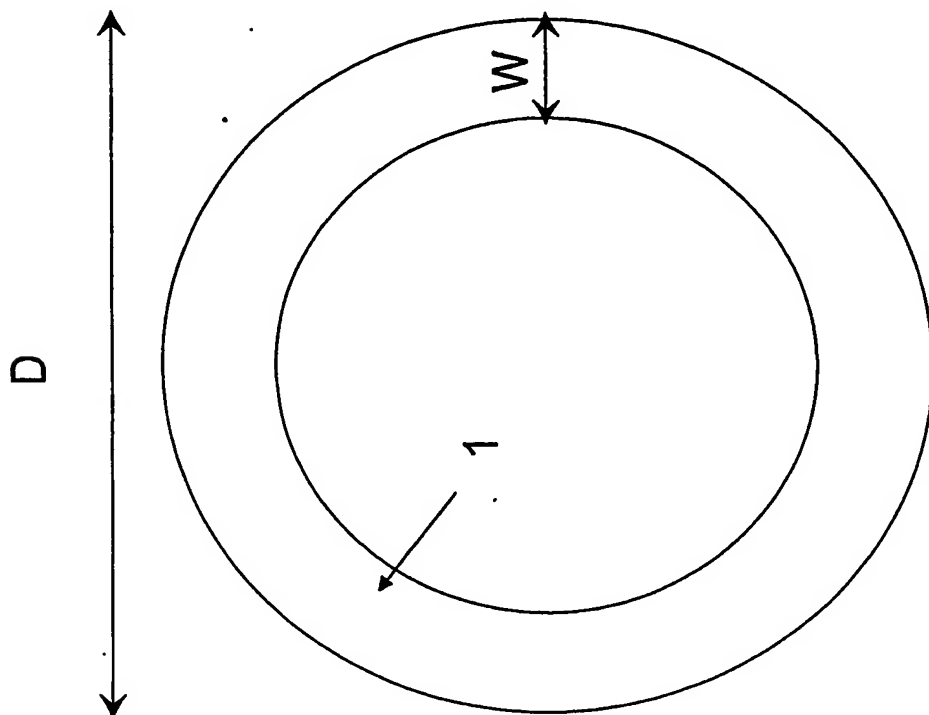


Fig. 1



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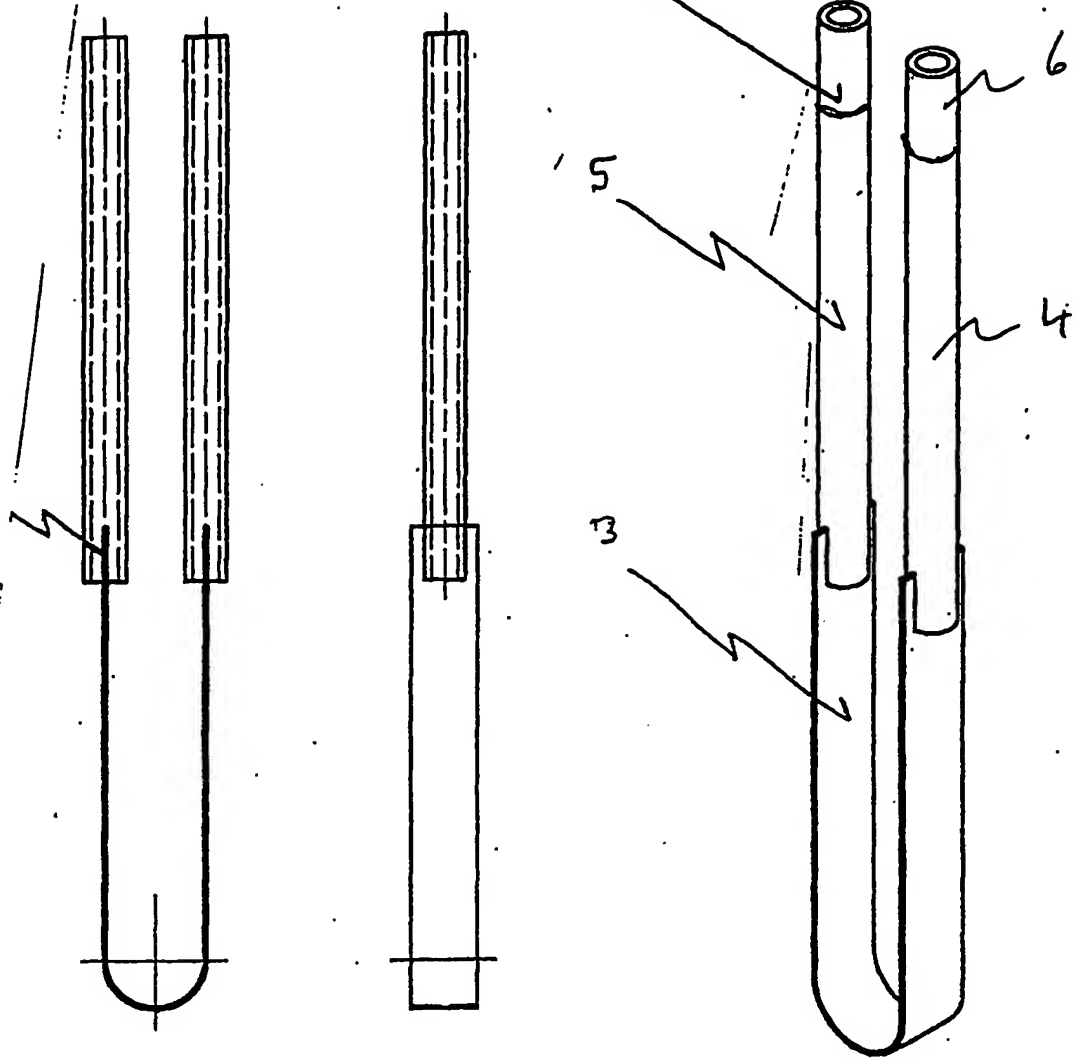


Fig 3

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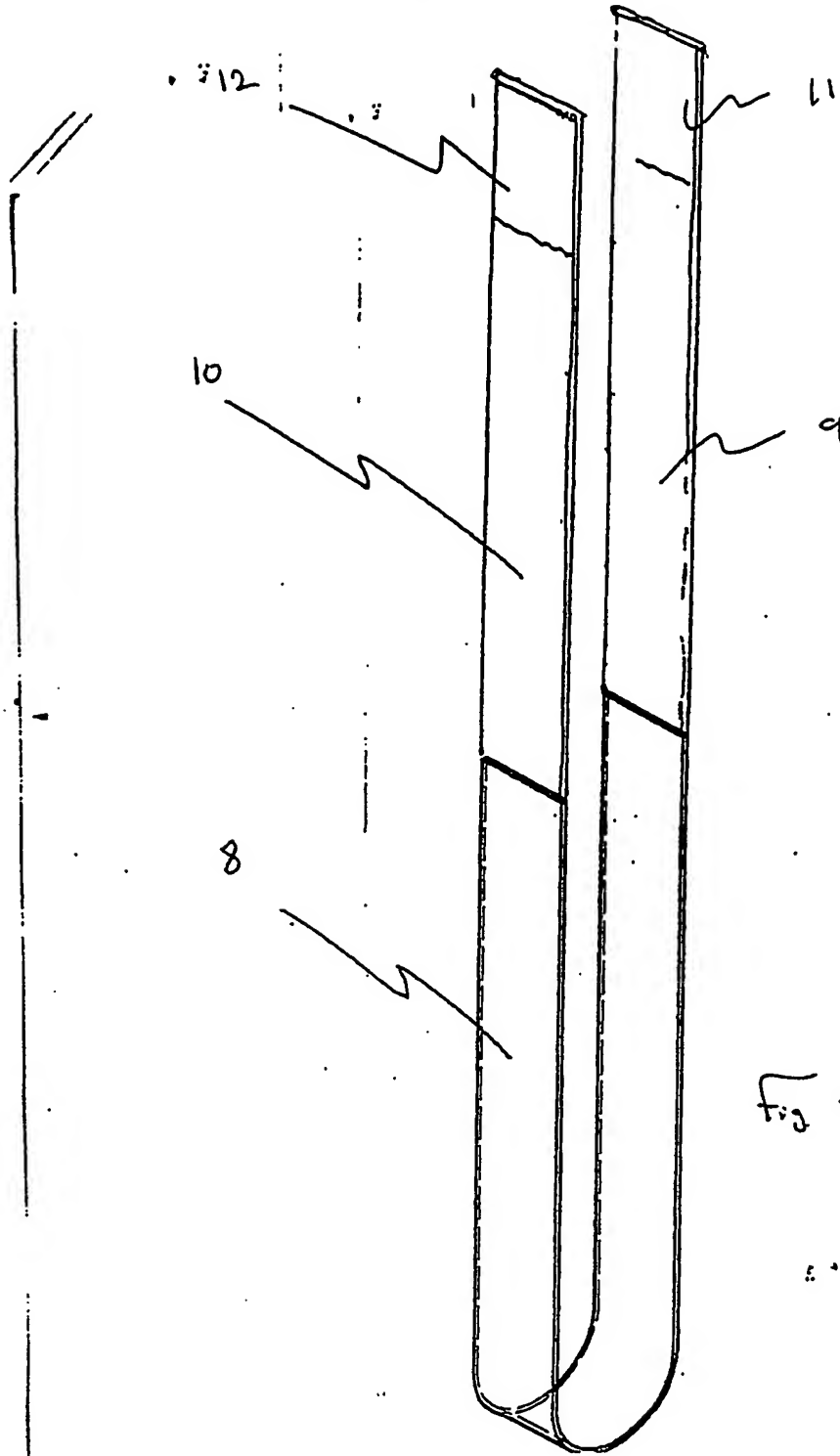


Fig 4

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Fig. 6

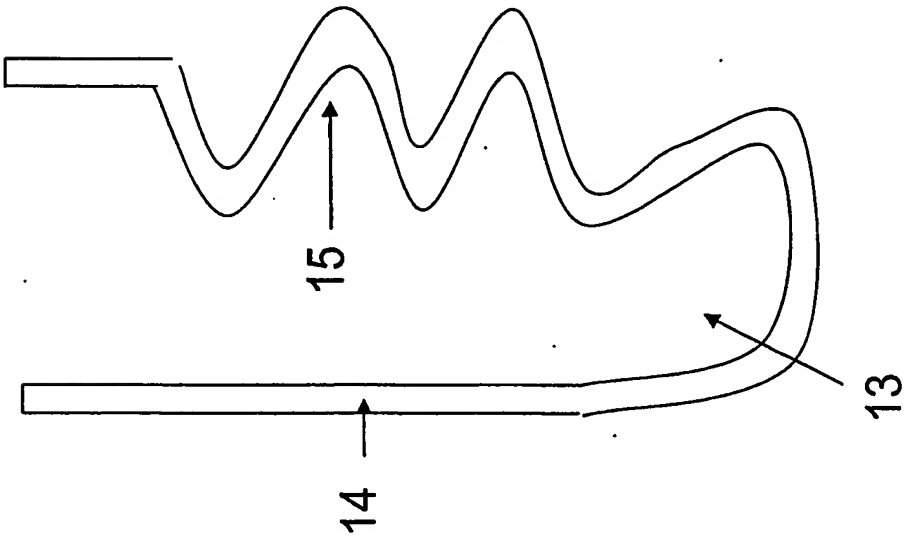
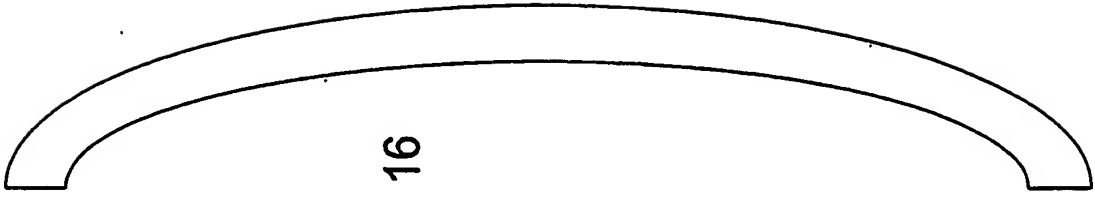


Fig. 5

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